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THE EFFECT OF HERBICIDES ON THE PROTEIN CONTENT IN TUBERS OF EDIBLE POTATO CULTIVARS

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ABSTRACT

Background. The aim of the study was to determine the effect of selected methods of weed control on the content of total and true protein in tubers of three cultivars of edible potato.

Material and methods. The two-way field experiment was carried out in a split-plot design in three replications. The studied factors included: I – three potato cultivars: Cekin, Satina and Tajfun. II – five methods of weed control: (1) mechanical treatment – control plot, (2) mechanical treatment + herbicide Command 480 EC at a rate of 0.2 $dm^3 \cdot ha^{-1}$, (3) Mechanical treatment + herbicidal combination Command 480 EC at a rate of 0.2 $dm^3 \cdot ha^{-1}$ + Afalon Dyspersyjny 450 SC at rate of 1.0 $dm^3 \cdot ha^{-1}$, (4) Mechanical treatment + herbicide Stomp 400 SC at a rate of 3.5 $dm^3 \cdot ha^{-1}$, (5) mechanical treatment + herbicidal combination Stomp 400 SC at rate of 3.5 $dm^3 \cdot ha^{-1}$ + Afalon Dyspersyjny 450SC at a rate of 1.0 $dm^3 \cdot ha^{-1}$.

Results. The highest contents of total and true protein as compared with the control plot were obtained on plots where the herbicidal combination Stomp 400 SC + Afalon Dyspersyjny 450 SC was used and the herbicide Stomp 400 SC by itself was used. The research results indicated that cv. Satina was characterized by the highest concentration of total protein, on average 12.98% d.m., and of true protein with the average being 8.60% d.m, while cv. Tajfun had the lowest content of the discussed nutrients, 12.04 and 8.08% respectively, of the dry weight of tubers. Weather conditions over the years of research varied the content of both total and true protein. The highest content of total and true protein was found in tubers in 2009, which was characterized by the most optimal rainfall total and air temperature for potato development experienced during our study.

Conclusion. Herbicides applied in the experiment as well as weather conditions in particular years of research contributed to a diversified content of total and true protein in potato tubers. The content of the discussed component was also determined by varieties cultivated in the experiment.

Key words: chemical treatment, mechanical and chemical treatment, mechanical treatment, total protein, true protein

INTRODUCTION

Potato, like wheat, maize and rice, is a staple crop that is crucial for feeding the world's population. It owes its nutritional value to easily-digestible carbohydrates and the presence of highly valuable protein with a favourable amino acid composition, which contains a lot of lysine, leucine, threonine and phenylalanine. The nutritive value of potato protein is comparable with the nutritive value of chicken egg protein and exceeds the quality of proteins in other plants (Eppendorfer and Eggun, 1994, Stankiewicz *et al.*, 2008, Zgórska, 2013, Nemś *et al.*, 2015).

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The chemical composition and quality of potato tubers are mainly determined by cultivar properties, which undergo a major or minor modification under the effect of agronomic treatments as well as from climatic and soil conditions (Kołodziejczyk, 2014).

In the present study a research hypothesis was assumed that although protein content in potato cultivars is a genetic trait, a herbicidal treatment, besides effectively reducing weed infestation, may also cause changes in the chemical composition of potato. The aim of the study was to determine the effect of herbicides, used in weed control on a potato plantation, on the content of total and true protein in tubers of three cultivars of edible potato.

MATERIAL AND METHODS

The field experiment was carried out in the years 2008-2010 on the Experimental Farm in Zawady (52°03' N; 22°33' E) that is located in the south of the Podlasie region and is the property of the Siedlce University of Natural Sciences and Humanities. The two-way experiment was set up in a split-plot design in three replications.

The experiment included:

I – factor – potato cultivars: Satina, Tajfun, Cekin,

II – factor – five methods of weed control: 1) mechanical treatment – control plot, 2) mechanical and chemical treatment, i.e. until emergence, hilling combined with harrowing, and about 7 days before emergence spraying with the herbicide Command 480 EC 0.2 $dm^3 \cdot ha^{-1}$, 3) mechanical and chemical treatment, i.e. until emergence, hilling combined with harrowing, and about 7 days before emergence spraying with a combination of herbicides Command 480 EC 0.2 $dm^3 \cdot ha^{-1}$ + Afalon Dyspersyjny 450 SC 1.0 $dm^3 \cdot ha^{-1}$, 4) mechanical and chemical treatment, i.e. until emergence, hilling combined with harrowing, and about 7 days before emergence spraying with the herbicide Stomp 400SC 3.5 $dm^3 \cdot ha^{-1}$, 5) mechanical and chemical treatment, i.e. until emergence, hilling combined with harrowing, and about 7 days before emergence spraying with a combination of herbicides Stomp 400SC 3.5 $dm^3 \cdot ha^{-1}$ + Afalon Dyspersyjny 450SC 1.0 $dm^3 \cdot ha^{-1}$.

Characteristics of the herbicides applied in the experiment are presented in Table 1.

The field experiment was set up on a soil included in the order: lessive soils, type: lessive soils, subtype: lessive soils, sandy, of a very good rye complex (Marcinek and Komisarek, 2011). The soil was characterized by a slightly acidic reaction, very high content of phosphorus, high content of potassium, and an average content of magnesium. Potatoes were cultivated on plots after winter cereals. In the experiment, organic fertilization with manure was applied at a rate of: 25 $t \cdot ha^{-1}$, and mineral fertilization at a rate of: 100 $kg \cdot ha^{-1}$ N, 44.0 $kg \cdot ha^{-1}$ P and 124.5 $kg \cdot ha^{-1}$ K. Insecticides and fungicides were applied according to requirements in accordance with recommendations of the Institute of Plant Protection.

Potatoes were harvested at the stage of processing maturity in the first decade of September. During harvest, samples of potato tubers were collected from each plot (30 potatoes from each one) for chemical analyses. Preliminarily prepared samples (cleaned and mixed) were stored until the time of carrying out chemical analyses (two days), in paper bags, at a temperature of 18-20°C.

Chemical analyses were conducted on dry material obtained after drying at 55°C. The content of total and true protein was calculated from the content of total and protein nitrogen, with the use of the coefficient 6.25. The total and protein nitrogen was determined with Kjeldahl's method on a 2300 Kjeltec Analyser Unit (Ostrowska *et al.*, 1991). Insoluble true protein was determined with Kjeldahl's method; before determination, protein was separated from non-protein nitrogen compounds through precipitation with 10% trichloroacetic acid (TCA) .

The research results were elaborated statistically with the analysis of variance. Significance of the sources of variation was determined with the Fischer--Snedecor distribution, while an evaluation of significance of differences with a significance level of $P = 0.05$ between the compared means was determined with the use of Tukey's range test (Trętowski and Wójcik, 1988).

The characteristics of humidity and thermal conditions during the period of research is presented in Table 2. According to the calculated Sielianinov's hydrothermal coefficient, the growing season of 2008

was optimal (k = 1.39), 2009 – quite dry (k = 1.28), 2010 – quite humid (k = 1.61). The highest rainfall was observed in the growing season in 2010, 459.7 mm, and the average air temperature was higher by 0.9°C compared with the long-term mean. The lowest rainfall total, 354.4 mm, was observed in 2009, while the mean air temperature was higher by 0.4°C than the long-term mean. The growing season of 2008 was characterized by a rainfall total on the level of 371.4 mm, while the air temperature did not differ from the long-term mean and was 14.7°C.

Table 1. Characteristics of herbicides used in the experiment

Herbicide	Active substance	Chemical group
Command 480 EC	Clomazone	Dinitroanilines
Afalon Dispersion 450 SC	linuron	Isoxazolidinons of urea derivatives
Stomp 400SC	Pendimethalin	dinitroanilin

Table 2. Weather conditions in potato growing season in the years 2008-2010 (Zawady Meteorological Station)

Year	Month						
	April	May	June	July	August	September	April-September
	Rainfall, mm						Total
2008	28.2	85.6	49.0	69.8	75.4	63.4	371.4
2009	8.1	68.9	145.2	26.4	80.9	24.9	354.4
2010	10.7	93.2	62.6	77.0	106.3	109.9	459.7
Long-term total (1987-2000)	38.6	44.1	52.4	49.8	43.0	47.3	275.2
	Air temperature, °C						Mean
2008	9.1	12.7	17.4	18.4	18.5	12.2	14.7
2009	10.3	12.9	15.7	19.4	17.7	14.6	15.1
2010	8.9	14.0	17.4	21.6	19.8	11.8	15.6
Long-term mean (1987-2000)	7.8	12.5	17.2	19.2	18.5	13.1	14.7
	Sielianinov's hydrothermal coefficient*						Mean
2008	1.04	2.18	0.94	1.25	1.36	1.73	1.39
2009	0.26	1.72	3.08	0.44	1.48	0.57	1.28
2010	0.40	2.14	1.20	1.15	1.74	3.10	1.61

* Value of Sielianinov's coefficient (Skowera i Puła, 2004)
Extremely dry (ss) $k \leq 0.4$, very dry (bs) $0.4 < k \leq 0.7$, dry (s) $0.7 < k \leq 1.0$, quite dry (ds.) $1.0 < k \leq 1.3$, optimal (o) $1.3 < k \leq 1.6$, quite humid (dw) $1.6 < k \leq 2.0$, humid (w) $2.0 < k \leq 2.5$, very humid (bw) $2.5 < k \leq 3.0$, extremely humid (sw) $k > 3.0$

RESULTS AND DISCUSSION

From the conducted research it can be seen that the content of total and true protein depended significantly on the cultivated cultivars, methods of treatment and the weather conditions in particular years of the research (Table 3 and 4).

According to Bàrtova *et al.* (2009), Wichrowska *et al.* (2009), Kołodziejczyk *et al.* (2010) as well as Gugała *et al.* (2014), protein content in potato tubers is determined by genetic properties of the cultivars.

Our study results proved that among the cultivated cultivars, the highest concentration of total protein, on average 12.98% d.m., and true protein on average 8.60% d.m., was characteristic of tubers of cv. Satina, while the lowest levels of the discussed components were contained in tubers of cv. Tajfun, 12.04 and 8.085% of dry matter, respectively. Our research results are in line with Wierzbicka and Trawczyński (2012), who found variation in protein content that depended on cultivar type. According to them, the highest protein content in the fresh matter of potato tubers was characteristic of early edible cultivars, a slightly lower content in second early cultivars and late season edible cultivars, and the lowest protein content was characteristic of cultivars high in starch.

Herbicides and their combinations applied in our experiment caused an average increase in the total protein content from 12.01 to 12.77% d.m., and in the true protein content from 7.941 to 8.628 % of the dry matter of tubers.

Significantly the highest content of total and true protein compared with the control was obtained on the plots where the herbicide combination Stomp 400 SC + Afalon Dyspersyjny 450 SC on average 12.77% and 8.628%, respectively (Tables 3 and 4). These results are similar to the studies of Arora *et al.* (2009), who obtained the highest protein content after applying a herbicide containing pendimethalin. The studies of Wichrowska *et al.* (2009) also indicated that tubers from plots sprayed with herbicides contained up to 3.7% more protein than tubers of plants that only had mechanical treatment. Similarly, Zarzecka and Gugała (2006) observed an increased concentration of total protein after spraying with herbicides: Plateen 41.5 WG as well as Plateen 41.5 WG + Fusilade Forte 150 EC and Barox 460 SL as well as Barox 460 SL + Fusilade Forte 150 EC.

Table 3. The content of total protein in the dry matter of potato tubers, %

Weed control methods	Cultivar			Year			Mean
	Cekin	Satina	Tajfun	2008	2009	2010	
1) control plot	11.56	12.79	11.70	11.61	12.38	12.05	12.01
2) Command 480 EC – 0.2 $dm^3 \cdot ha^{-1}$	12.01	12.85	11.94	12.12	12.51	12.17	12.27
3) Command 480 EC – 0.2 $dm^3 \cdot ha^{-1}$ + Afalon Dysp. 450 SC – 1.0 $dm^3 \cdot ha^{-1}$	12.33	12.97	12.04	12.39	12.66	12.29	12.45
4) Stomp 400SC – 3.5 $dm^3 \cdot ha^{-1}$	12.65	13.12	12.20	12.57	12.74	12.66	12.66
5) Stomp 400SC 3.5 $dm^3 \cdot ha^{-1}$ + Afalon Dysp. 450 SC 1.0 $dm^3 \cdot ha^{-1}$	12.87	13.15	12.30	12.72	12.81	12.79	12.77
Mean	12.28	12.98	12.04	12.28	12.62	12.39	–
$LSD_{0,05}$ for:							
years 0.17 cultivars 0.17 weed control methods 0.23							
interaction							
weed control methods × cultivars ns							
weed control methods × years ns							

ns – non-significant

Table 4. The content of true protein in the dry matter of potato tubers, %

Weed control methods	Cultivar			Year			Mean
	Cekin	Satina	Tajfun	2008	2009	2010	
1) control plot	7.661	8.437	7.724	7.436	9.010	7.376	7.941
2) Command 480 EC – 0.2 $dm^3 \cdot ha^{-1}$	7.961	8.623	8.041	8.055	9.160	7.414	8.210
3) Command 480 EC – 0.2 $dm^3 \cdot ha^{-1}$ + Afalon Dysp. 450 SC – 1.0 $dm^3 \cdot ha^{-1}$	8.354	8.743	8.142	8.352	9.260	7.624	8.412
4) Stomp 400SC – 3.5 $dm^3 \cdot ha^{-1}$	8.587	8.443	8.210	8.355	9.040	7.843	8.413
5) Stomp 400SC 3.5 $dm^3 \cdot ha^{-1}$ + Afalon Dysp. 450 SC 1.0 $dm^3 \cdot ha^{-1}$	8.823	8.755	8.310	8.583	9.400	7.901	8.628
Mean	8.277	8.600	8.085	8.156	9.175	7.631	–
$LSD_{0,05}$ for:							
years 0.171 cultivars 0.171 weed control methods 0.233							
interaction							
weed control methods × cultivars ns							
weed control methods × years ns							

ns – non-significant

On the other hand, Pszczółkowski and Sawicka (2009) indicated that all their methods of mechanical and chemical treatment with the use of single herbicides or their combinations caused a decrease in the concentration of total and true protein in potato tubers.

The effect of weather conditions during the growing season on the protein content in potato tubers is also reported by Zrůst and Hola (1994), Lachman *et al.* (2005), Bàrtova *et al.* (2009). Weather conditions occurring in the particular growing seasons of our study significantly varied the content of both total and true protein (Tables 2, 3 and 4). The highest amounts of the discussed components were accumulated in tubers harvested in 2009 (Tables 3 and 4), a year that was characterized by an amount of rainfall and average air temperatures similar to the long term mean (Table 2). These results are similar to studies conducted by many researchers: Wierzbicka and Trawczyński (2012), Gugała *et al.* (2014), Kołodziejczyk (2014) as well as Makarewicz *et al.* (2014). They also found that the highest protein content was characteristic of tubers harvested in the years with a lower rainfall total and a higher air temperature, while the lowest amount of the discussed component was obtained in the years with the highest rainfall total. However, a different opinion was expressed by Puła and Skowera (2004) as well as by Kołodziejczyk and Szmigiel (2012), who obtained the highest protein content in the years characterized by high rainfall and low air temperature.

CONCLUSIONS

1. Herbicides and their combinations used in this study resulted in an increase in the content of total and true protein in potato tubers when compared with the control plot on which only mechanical treatment was applied.
2. The highest content of total and true protein was characteristic of tubers of cv. Satina, which indicates its higher nutritional value and high suitability for consumption purposes.
3. Conditions occurring in particular years of the research determined the content of total and true protein in potato tubers. The highest content of these components was obtained in the year characterized by rainfall and air temperatures similar to multiyear means in the south of the Podlasie region.

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WPŁYW HERBICYDÓW NA ZAWARTOŚĆ BIAŁKA W BULWACH JADALNYCH ODMIAN ZIEMNIAKA

Streszczenie

Celem badań było określenie wpływu wybranych sposobów ochrony plantacji przed chwastami na zawartość białka ogólnego i właściwego w bulwach trzech odmian ziemniaka jadalnego. Doświad-czenie polowe, dwuczynnikowe przeprowadzono w układzie split-plot w trzech powtórzeniach. Badanymi czynnikami były: I – trzy odmiany ziemniaka: Cekin, Satina i Tajfun, II – pięć sposobów odchwaszczania: 1) pielęgnacja mechaniczna – obiekt kontrolny, 2) pielęgnacja mechaniczna + herbicyd Command 480 EC w dawce 0,2 $dm^3 \cdot ha^{-1}$, 3) pielęgnacja mechaniczna + mieszanina herbicydów Command 480 EC w dawce 0,2 $dm^3 \cdot ha^{-1}$ + Afalon Dyspersyjny 450 SC w dawce 1,0 $dm^3 \cdot ha^{-1}$, 4) pielęgnacja mechaniczna + herbicyd Stomp 400 SC w dawce 3,5 $dm^3 \cdot ha^{-1}$, 5) pielęgnacja mechaniczna + mieszanina herbicydów Stomp 400 SC w dawce 3,5 $dm^3 \cdot ha^{-1}$ + Afalon Dyspersyjny 450SC w dawce 1,0 $dm^3 \cdot ha^{-1}$. Największą zawartość białka ogólnego i właściwego w porównaniu z obiektem kontrolnym uzyskano na poletkach, na których zastoso-wano mieszaninę herbicydów Stomp 400 SC + Afalon Dyspersyjny 450 SC oraz herbicyd Stomp 400 SC. Wyniki badań dowiodły, że odmiana Satina charakteryzowała się największą koncentracją białka ogólnego – średnio 12,98% s.m. i białka właściwego – średnio 8,60% s.m, zaś najmniejszą zawartość omawianych składników miała odmiana Tajfun, odpowiednio 12,04 i 8,08% suchej masy bulw. Warunki atmosferyczne w latach prowadzenia badań różnicowały zarówno zawartość białka ogólnego, jak i właściwego. Naj-większą zawartość białka ogólnego i właściwego w bulwach stwierdzono w 2009 roku, charakteryzującym się najbardziej optymalną dla rozwoju ziemniaka ilością opadów i temperaturą powietrza.

Słowa kluczowe: białko ogólne, białko właściwe, pielęgnacja chemiczna, pielęgnacja mechaniczna, pielęgnacja mechaniczno-chemiczna